NASA TECH BRIEF

Economic Method for Measuring Ultra-Low Flow Rates of Fluids

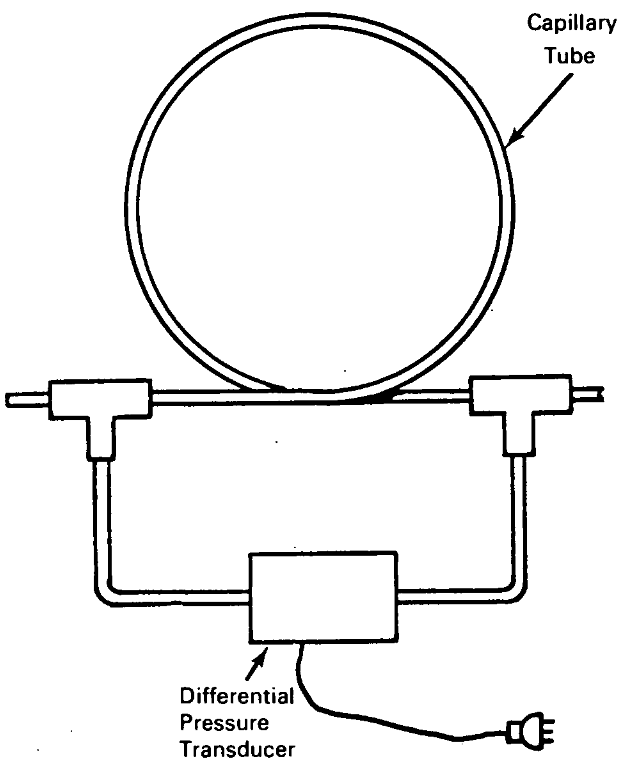

Figure 1. Capillary Tube Flowmeter

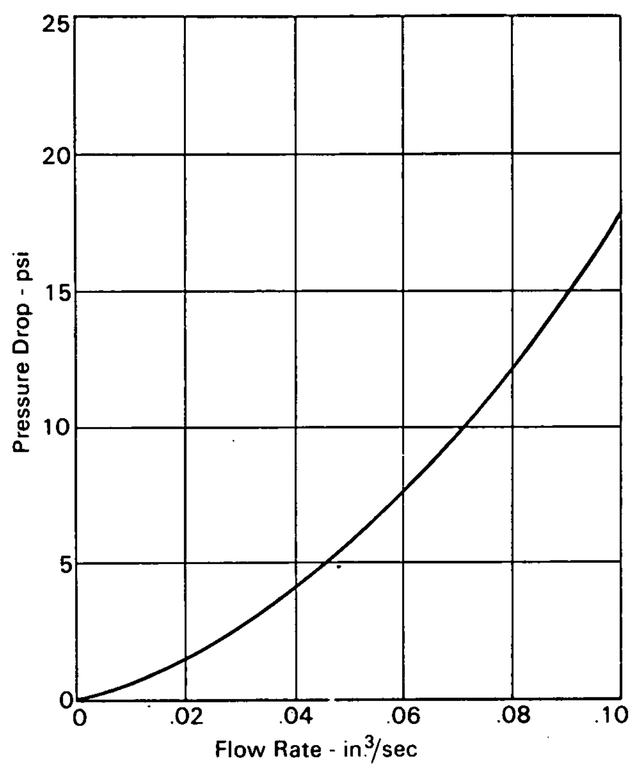

Figure 2. Capillary Tube Flowmeter - Pressure Drop Versus Flow Rate for Chlorine Trifluoride

A capillary tube flowmeter has been designed to measure ultra-low flows of corrosive and other liquids. The method used is economical and should be of interest to the chemical industry.

A differential pressure transducer is used which measures the linear pressure drop across a coil of capillary tubing. Through calibration with water and analytical conversion, flow rates of very corrosive fluids (such as chlorine trifluoride and liquid fluorine) as low as 0.005 gpm can be measured with reasonable accuracy.

The essential elements of the capillary tube flowmeter, shown in Figure 1, include 4 feet of 1/16-in. tubing and a differential pressure transducer. The flowmeter operates on the principle that for laminar flow in the tube, the pressure drop is proportional to the flow rate. Since the capillary tube is smaller in diameter than the rest of the system's lines, reducers

(continued overleaf)

are required at each end of the line. The abrupt changes in line size are also sensed by the differential pressure transducer and should follow the pressure drop function. The total pressure drop which a transducer will thus sense is expressed by the formula

$$P = K_1Q^2 + K_2Q$$

where Q is the fluid flow, and K_1 and K_2 are functions of the fluid flowing through the meter and the meter geometry. The calibration test using water results in one set of values for K_1 and K_2. Once the meter has been calibrated with water, it is simple to modify the equation for any liquid. The coefficients K_1 and K_2 are proportional to the viscosity and density ratios of the liquid to water, respectively. Applying the viscosity and density for chlorine trifluoride, the result is

$$P = 1314Q^2 + 45.7Q$$

which is shown graphically in Figure 2.

During valve opening and closing transients, flow measurements cannot be made because of cavitation or water hammer in the differential pressure transducer lines. Once the valve transient has damped out, the flowmeter reading can be made with reasonable accuracy. The flowmeter error at the design flow rate of about 0.03 in.^{3}/sec is $\pm$ 0.002 in.^{3}/sec if a differential pressure transducer error of $\pm$ 0.25 psi is assumed. The flow rate error can be shown mathematically to be a function of pressure differential and pressure differential error.

Note:

No additional documentation is available. Specific questions, however, may be directed to:

Technology Utilization Officer
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Patent status:

No patent action is contemplated by NASA.

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